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Abundance and Length, Trap Avoidance, and Short-Term Spatial Movement of Cutthroat Trout at McKinney Lake, Southeast Alaska, 1996

by

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_0
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

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ABSTRACT

A lake-dwelling population of cutthroat trout *Oncorhynchus clarki* at McKinney Lake on Admiralty Island, Southeast Alaska, was systematically sampled on three occasions between May 31 and August 14, 1996 using baited hoop traps and hook and line gear. Abundance and length composition were estimated and vertical and horizontal movements of recaptured fish were documented. Catch rates and fractions of marked fish found along the margins, bottom, and center ("pelagic" area) of the lake were compared over time. Mid-water traps and trolling with lures were used to sample the pelagic area of the lake. We tested for trap avoidance behavior and whether recapture rates differed significantly for fish marked with anchor T-bar and Visible Implant tags.

Significant avoidance of baited hoop traps (relative to hook and line) and effects related to tag type were not detected. However, experimental power was much lower than planned due to difficulties in recapturing the desired number of marked fish.

Recaptured fish traveled horizontal distances of up to 3,085 meters, but the majority (57%) traveled 300 meters or less. Vertical movement ranged up to 18 meters, but one-half of the recaptured fish moved 3 meters or less. Time at large (18 to 72 days) was not an important factor in the vertical or horizontal distance traveled between captures.

The estimated abundance of cutthroat trout ≥180 mm FL in McKinney Lake was 3,756 (SE = 798). Stratification of the experiment by depth and area was needed to reduce bias in the estimate. Marked fractions differed significantly between shoreline and offshore areas over the time of sampling perhaps due to limited fish movements. If this occurs in other lakes, complete mixing of marked fish may not occur during a typical two-event experiment to estimate abundance of cutthroat trout. Thus, equal probability of capture assumptions may be critically important in these experiments.

Key words: Alaska, McKinney Lake, cutthroat trout, abundance, mark-recapture, sampling, length composition, horizontal and vertical movement, mixing.

INTRODUCTION

Lake-dwelling populations of cutthroat trout *Oncorhynchus clarki* in the Tongass National Forest, Southeast Alaska, have been of considerable interest to the Alaska Department of Fish and Game (ADF&G) and the United States Forest Service (USFS) over the last 10 years. Recent studies have focused on estimating abundance (e.g., Jones et al. 1992, Schmidt 1994, Der Hovanisian and Marshall 1995, Harding 1995, Freeman et al. 1998, Schmidt et al. 1998), fish age and surplus production (Ericksen 1997), and assessment methods and population dynamics (Laker 1994, Ericksen 1997, Rosenkranz et al. 1999). These studies have significantly increased our knowledge regarding trout abundance and age and size in representative lakes of Southeast Alaska, and have provided a succession of insights about efficacious assessment methods for the species.

One objective of this study was to estimate abundance and length composition of cutthroat trout in this increasingly popular destination in the Admiralty Island National Monument. ADF&G and the USFS jointly conducted this study in 1996 to inventory the resource. Abundance was estimated using a two-event closed population (CP) mark-recapture (m-r) experiment similar in design to that used in most of our studies. The moderate size and depth of McKinney Lake also encouraged us to investigate two specific cases of an assumption of our m-r experiments: that marking does not effect catchability of the animal (Seber 1982:59).

One of these two investigations tested whether cutthroat trout captured with baited hoop traps (BHT) and marked during the first sampling trip of the experiment tended to avoid recapture with BHT two weeks later. This assumption was tested by comparing recapture rates with BHT to recapture rates with hook and line (H&L). The second investigation tested whether recapture rates differed significantly for fish initially marked with anchor T-bar and Visible Implant (VI) tags.

These two experiments were termed the "trap avoidance" and "tag effect" studies, respectively. The "trap avoidance" study was suggested (as one of several topics to investigate) while we contemplated preliminary results (see Freeman et al. 1998, Rosenkranz et al. 1999) in which huge (50–100%) discrepancies existed between abundance estimates generated from intra-annual (CP) and inter-annual (Jolly-Seber) m-r experiments on the same populations. While Freeman et al. (1998) and Rosenkranz et al. (1999) ultimately concluded that trap avoidance did not cause these differences, our experiments at McKinney Lake contributed to this understanding.

During our analysis we also compiled statistics and data summaries that we believed to be of general interest to researchers working with lacustrine trout, and these summaries are also featured in this report. In particular, we describe the vertical and horizontal movements of recaptured fish, and compare catch rates and fractions of marked fish (m/c ratios) found along the margins, bottom, and center ("pelagic" area) of the lake over time. These results are of interest because little is known about the relative distribution and habitat use of cutthroat trout in lakes, and the efficacy of BHT and H&L to obtain representative samples can be difficult to determine (see Havens et al. 1992, Der Hovanisian and Marshall 1995, Rosenkranz et al. 1999). New (or seldom used) methods for sampling with BHT and lures in *offshore surface* waters (or pelagic areas) of the lake were also tested at McKinney Lake. We reasoned that if catches in the pelagic areas where fishing seldom occurs were relatively high, hypotheses regarding the mixing of marked fish between bottom and pelagic areas of the lake might be usefully evaluated. Then, the efficacy of shore- and bottom-oriented sampling designs to estimate population parameters for lake-dwelling cutthroat trout might be evaluated more closely.

STUDY AREA

McKinney Lake lies within the Admiralty Island National Monument of the Tongass National Forest (Figure 1). The lake is approximately 126 ha in surface area and is accessible by floatplane or a 0.8 km trail from Hasselborg Lake. About half of the lake is less than 10 m in depth, and about 15% is deeper than 30 m. Maximum depth of the lake is 40–50 m. There are no USFS recreational cabins at the lake, and the ADF&G sport fishing harvest survey (Howe et al. 1998) has not estimated the relatively low recreational fishing use of the lake.

A research survey of the fish populations at McKinney Lake using variable mesh gill nets occurred in 1968 (ADF&G, *Unpublished*). Catches were 58 cutthroat trout (115 to 295 mm FL) and 7 Dolly Varden *Salvelinus malma* (190 to 245 mm FL). Kokanee *Oncorhynchus nerka* and "large-sized" cutthroat trout were thought to be present in the lake although none were caught in the gillnet survey.

METHODS

Sampling trips from May 31 through June 9, from June 25 through July 3, and from August 5 through August 14, 1996 were made to mark and sample cutthroat trout. Only BHTs were used to capture fish during the first sampling trip. Cutthroat trout ≥ 180 mm FL in good physical condition were alternately marked with anchor T-bar and VI tags, sampled for scales, measured to the nearest mm FL, and returned to the lake. During the second trip BHT and H&L (i.e., lures) were used to capture fish. Marked and unmarked fish captured with BHT and H&L fished at similar locations and depths around the lake were used to test whether marked fish were equally susceptible to recapture following the first hiatus. Also, the numbers of marked fish in the second sample by tag type was compared to determine if a significant tagging effect could be detected during this hiatus. Abundance and length composition were estimated from samples collected during all three sampling trips: captures from trips 1 and 2 were pooled to make the first sampling event and captures from trip 3 made the second event.

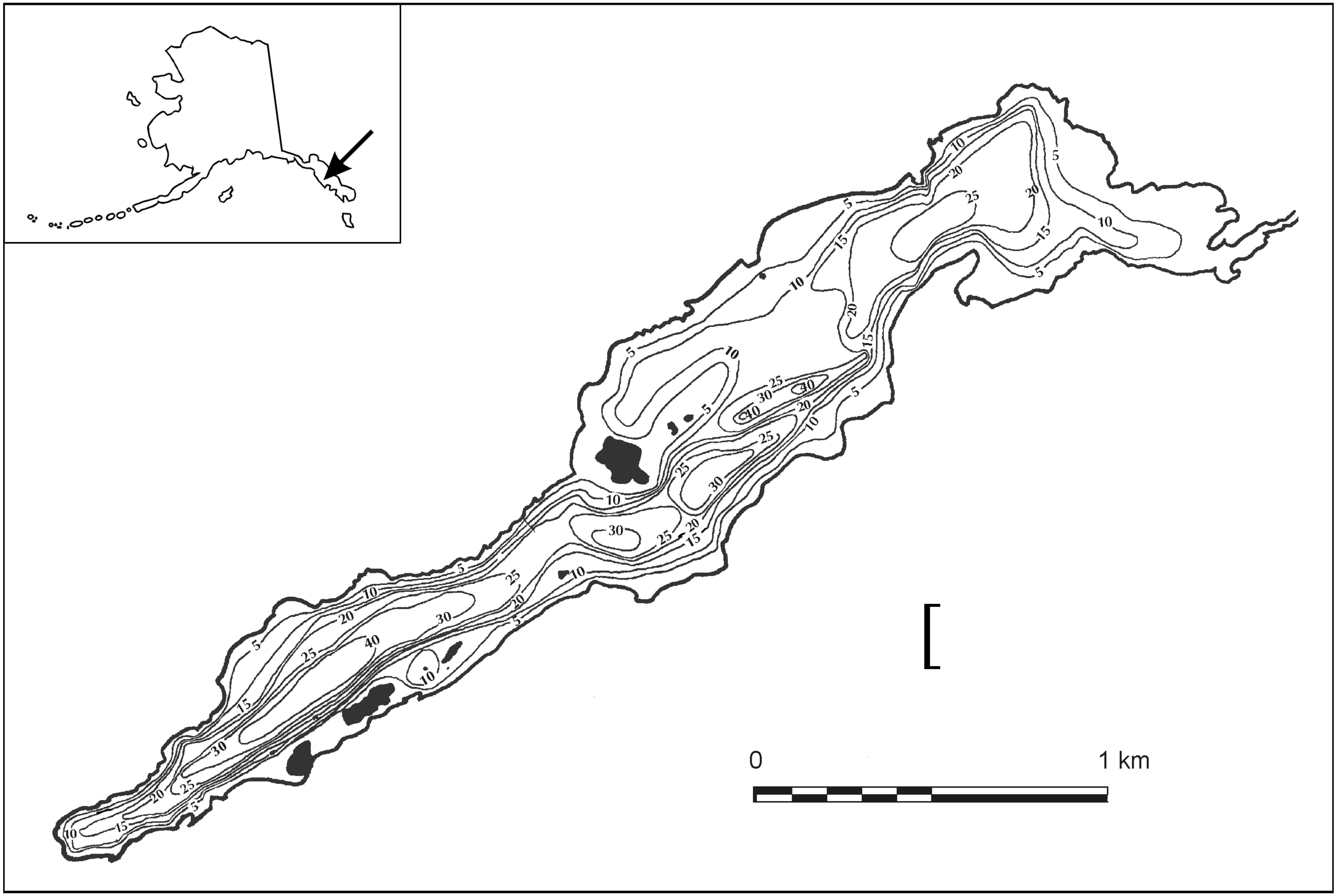

Figure 1.–Bathymetric map of McKinney Lake, Admiralty Island, Southeast Alaska. Dark areas are islands. Contours shown in 5-m intervals from 0 to 40 m (35-m contour not shown).

Details of each of the three sampling designs are provided below. All captured cutthroat trout <180 mm FL were measured, counted, and returned to the lake untagged.

Anchor T-bar tags were inserted diagonally into the musculature at the base of the dorsal fin with the numbered tag trailing at about a 45-degree angle (Dell 1968). VI tags were placed in the anal fins as described by Wenburg and George (1995). Unique secondary marks were applied during each sampling trip (Table 1) to enable estimates of tag loss, and prevent double sampling. Betadine-treated salmon eggs were used as bait in the BHTs, which were 1.4 m in length and consisted of four 0.6-m diameter hoops, with 9-cm-diameter throats attached to the first and third hoops, and a mesh size of 1 cm.

Superimposing a grid of 75 similar sized areas over a bathymetric map of the lake facilitated sampling and data recording. The grid-map allowed crew members to locate approximately any location (area) on the lake surface specified in the sampling plan. Because cutthroat trout are rarely captured at depths >30 m (e.g., Benson 1961), sampling gear was not set in 5 areas dominated by depths >30 m, which left 70 areas to sample. During the first sampling trip, a systematic selection of 35 of the 70 grid locations (i.e., every odd or even numbered area) was used to determine where to set the BHT on the first day. Afterwards the areas sampled alternated each day. Technicians arbitrarily selected a sampling point within each of the selected areas, set a BHT on the lake bottom, and marked it with a small float.

During the second trip, one-third of the numbered grid areas were systematically selected for fishing BHT on the first day. Afterwards, sampled locations rotated every three days. In addition, a total of 16 hours of H&L fishing (with lures) were expended each day by four anglers in two boats. Lures were fished by casting from the boat in shallow water (≤ 6 m) and by trolling (with the aid of a downrigger) near the lake bottom in deeper water. The grid locations and approximate depth of capture based on downrigger and/or sonar readings were recorded for fish captured by trolling or BHT. Depths of fish caught by casting lures near shore (≤6 m) were not estimated.

Table 1.—Secondary marks applied by sampling trip and primary (numbered) tag type, McKinney Lake, 1996.

Trip	Primary tag type	
	T-bar	VI
1	Upper caudal	Adipose
2	Lower caudal	Adipose + lower caudal
3	Upper caudal	Adipose + upper caudal

During the third sampling trip, H&L effort (casting lures) along the shoreline was increased at the expense of trolling lures in deep water (trolling was relatively inefficient, and thus unnecessary after trip 2). BHT were set as in trip 2, and 10 additional BHT were set within a meter or two of shore.

Water temperature was measured several times during each 10-day sampling trip using a YSI^{TM} model 33 S-C-T meter with a submersible probe. Temperatures were measured at the surface, 0.5 m, and at 1-m intervals in the area of the deepest water in the southwest end of the lake (Figure 1).

TRAP AVOIDANCE

The hypothesis that fish sampled in trip 1 with BHT tend to avoid recapture with BHT in trip 2 was tested by comparing the numbers of marked and unmarked fish captured with each gear type during the second sampling trip. Symbolically, the null hypothesis was $H_0 : p_1 \geq p_2$ where p_1 is the marked fraction in the BHT sample and p_2 is the marked fraction in the H&L sample. Our one-sided alternative was that marked fish avoid recapture in BHT ($H_a : p_1 < p_2$). The chi-square statistic (T, Conover 1980:145) was used to test this one-sided hypothesis. The critical value of the test statistic x_a (large sample approximation) was the α quantile of the standard normal distribution; we rejected Ho (α=0.1) if $T < -1.282$.

The avoidance experiment was predicated on an assumption that H&L and BHT fished the same homogenous population of marked fish during trip 2. In other words, if fish captured with BHT near/on the lake bottom during trip 1 did not mix completely with fish in other areas prior to the second sampling trip, the test would be invalid unless the H&L gear sampled the same lake bottom habitat sampled by BHT. Thus, we designed the experiment so that catches from BHT could be compared only to catches from trolling near the lake bottom, so that complete mixing was not a critical assumption. Samplers were instructed to troll within 6 m of the lake bottom at all times. Trolling occurred at a uniform speed, generally parallel to the shore to minimize boat steering, downrigger adjustment, and tangling of lines. Daily fishing effort was recorded as the number of hours of H&L sampling in each 10-m depth contour.

Target sample sizes for this experiment (608 fish with BHT in trip 1 and about 300 with BHT and downrigger-controlled H&L [DH&L] in trip 2) were estimated to enable detection of a 35% lower recapture rate in BHT with 80% confidence. This expected sensitivity, while low, was adequate to detect large (50–100%) biases in estimates of abundance from short-term CP experiments (see introduction). Target sample sizes were the maximum possible from a practical perspective given a crew of 4 and an anticipated population size of 2,200 fish. In particular, *a priori* estimates of catch per unit effort (CPUE) for DH&L and BHT dictated that sampling effort would largely be spent using DH&L (i.e., ≥16 of 32 crew-hours/day).

TAG EFFECT

The hypothesis that fish marked with anchor T-bar tags would be recaptured at equal or lower rates than fish marked with VI tags was tested by comparing the proportion of T-bar tags encountered during the second sampling trip to the proportion marked during the first event. The null hypothesis was $H_0 : p \le p_o$, where p is the proportion of the marked fish in the recapture sample that held VI tags and p_o is the proportion of fish marked in the first sample with VI tags (p_o was 0.50). The alternative hypothesis was that VI tags would be recaptured at higher rates than T-bar tags ($H_a : p > p_o$). The test statistic T was the number of VI tags in the sample. The critical value of the test statistic (α = 0.1) was calculated using the normal approximation (Conover 1980:444):

$$y_r = np + w_r\sqrt{np(1-p)} \qquad (1)$$

where n is the sample size (number of unique tags recovered) and w_r = 1.282 is the rth quantile of a standard normal random variable. We would reject H_0: if $T > y_r$. If “trap avoidance” (above) was observed, the result of the test would be investigated by gear type. Target sample sizes for this experiment (the same as for trap avoidance) would enable detection of a 30% lower recapture rate of anchor tags with 80% confidence. As noted above, this expected sensitivity was adequate to meet our objective and target sample sizes were believed to be as large as possible from a practical perspective.

ABUNDANCE

Lincoln-Petersen and Darroch CP models (Seber 1982:59,431) were used to estimate abundance, depending on whether stratification by area (ends or middle) of the lake or depth were necessary to meet modeling assumptions. Assumptions of the CP, single m-r experiment were:

1. the population was closed; i.e., both recruitment (or immigration) and death (or emigration) did not occur between sampling events;
2. every fish had an equal probability of being marked during the first event, <u>or</u> every fish had an equal probability of being sampled during the second event, <u>or</u> marked and unmarked fish mixed completely between events;
3. marking did not affect the catchability of a fish;
4. fish did not lose marks between events, <u>*and*</u> marks were recognized in the recovery sample.

The closure assumption was not tested directly. In a similar lake on Admiralty Island, spawning migrations to very small inlet streams begin in late

April and are concluded by early June (Harding 1995:27). Thus, it is possible that some spawning fish had not reentered the lake prior to the start of the first sampling trip on May 31. Since post-spawning fish are large relative to all fish sampled, such an immigration might be indicated if lengths of fish sampled increased substantially between trips. Similarly, significant growth recruitment between sampling events might be indicated if fish lengths declined significantly over time. A two-sample Kolmogorov-Smirnov (KS) test (Conover 1980) was used to detect significant differences in the lengths of fish caught between sampling trips.

Size-selective sampling (a violation of the second assumption) was investigated with two KS tests (Appendix A). If size-selective sampling occurred during the second sampling event ($P < 0.05$), the experiment was stratified by fish size to reduce bias. Appropriate strata for such an analysis were determined with a series of chi-square tests using 30-mm size classes. The scheme that produced the largest chi-square value (i.e., the greatest difference in capture probabilities) was employed to stratify the data.

Two chi-square tests (Seber 1982:438-39, Arnason et al. 1996) were also used to determine if the data were consistent with the second assumption. Data were compiled by marking and recovery area (ends and middle of the lake) and depth (above and below 6 m) and input to SPAS (Arnason et al. 1996) to complete these consistency tests, any beneficial data pooling, and to estimate abundance. The chi-square tests estimate probabilities that 1) fish marked in the different initial strata were recaptured at equal rates in the second sample, and 2) marked fractions were similar in each recovery stratum. If either of these tests yielded a non-significant result, strata were pooled to simplify the model. If all spatial strata are pooled, a Petersen model remained to estimate abundance. When geographically stratified models were needed, area and/or depth strata were pooled to find admissible (non-negative) estimates, reduce the number of estimated parameters and increase precision while finding no evidence of lack of fit (Arnason et al. 1996). Two main points were considered when pooling strata: the similarity of the fractions of fish marked (for recovery strata), and the similarity of recovery fractions (for marking strata). Pooling of neighboring strata that contained similar patterns of recoveries was also considered, in order to remove redundancy and to develop an intuitive basis for pooling.

The third assumption was investigated in our tests for “trap avoidance” (a specific behavior linked to the BHT), and an effect related to tag type as described above. Other possible effects, such as a generally lethargic reaction (lowered catchability) due to handling and tagging, were not investigated.

Assumption 4 should be robust in this experiment because all fish were double-marked and technicians were instructed to rigorously examine all captured fish for marks. Evidence of tag loss or tagging stress was recorded for every fish handled.

LENGTH COMPOSITION

Size-selectivity in sampling was investigated according to the protocols in Appendix A. When adjustment for size selective sampling was not needed, the proportion of fish in the population within length category *a* was estimated:

$$\hat{p}_a = \frac{n_a}{n} \tag{2}$$

$$\text{var}(\hat{p}_a) = \frac{\hat{p}_a\left(1-\hat{p}_a\right)}{n-1} \tag{3}$$

where n the number of fish measured for length and n_a is the number from this sample in length increment *a*.

The abundance in the population within length increment *a* was estimated (Goodman 1960):

$$N_a = \hat{p}_a \hat{N} \tag{4}$$

$$\begin{aligned}\text{var}[\hat{N}_a] = \text{var}(\hat{p}_a)\,\hat{N}^2 + \text{var}(\hat{N})\,\hat{p}_a^2 \\ - \text{var}(\hat{p}_a)\,\text{var}(\hat{N})\end{aligned} \tag{5}$$

where $\hat{N}$ is estimated abundance from the m-r experiment.

PELAGIC CATCH RATES

Our BHT and H&L fishing techniques were modified to increase their effectiveness in the normally unsampled offshore areas of the lake. Pelagic BHT traps (PBHT) were constructed by suspending BHT between a float and a weight resting on the lake bottom. Traps were rigged and set so that floats did not reach the lake surface. Thus, wave motions on the surface would not move the traps. A small auxiliary buoy marked the location of each trap. The PBHT were spaced evenly across the deeper portions of the lake and not relocated once set; fish movements alone caused fish-trap encounters. The number of pelagic traps fished each day varied from 9 traps in sampling trips 1 and 3, to 17 traps in trip 2. Fishing with PBHT was always >6 m above the lake bottom, but it typically occurred near the surface of the lake. H&L gear was also deployed in pelagic surface waters (PH&L) by trolling lures near the surface without use of a downrigger. Fishing depths with PH&L were <5 m.

FISH MOVEMENT

Horizontal and vertical movements between sampling trips were estimated for each recaptured fish where spatial information was complete. Horizontal movement of each fish was estimated by measuring the distance between the centers of the sampling areas where the captures occurred. Vertical movement was calculated by subtracting the depth of capture from depth of recapture and taking the absolute value. Since depth of capture was not recorded when lures were fished along shore or in pelagic surface areas, these data were omitted from the analysis. Data were plotted as a function of time between captures.

RESULTS

We captured a total of 1,368 cutthroat trout ≥180 mm FL and 4,907 Dolly Varden at McKinney Lake in 1996 (Table 2, Appendix A2). Total catch was similar for each trip despite the varied allocations of sampling effort by gear type. One cutthroat trout tagged at Hasselborg Lake in 1993 was captured during trip 1, showing that some fish move between these interconnected lakes in the Admiralty Island National Monument.

We tagged and released alive 414 unique cutthroat trout between 180 mm and 315 mm FL during the first sampling trip (May 31 to June 9) using BHT (Table 3). The majority (270 or 65%) of these 414 fish were captured at depths ≤ 6 m.

During the second sampling trip (June 25 to July 3), 395 unique cutthroat trout between 180 mm FL and 421 mm FL were inspected for marks; of these, 68 had been marked in the first sampling trip (Table 4). Excluding a single large (421 mm FL) fish, all others were ≤287 mm FL. Only one recaptured fish (originally marked with a VI tag) had lost its tag, indicating that tag loss through trip 2 was minimal (1.5%). Catch rates during both sample trips were much lower than expected; catch with BHT in sampling trip 1 was 68% of the desired total, while catches with BHT and DH&L in sampling trip 2 were only 45% and 14% of the desired totals.

A prominent result of sampling in trip 2 was the significantly lower fraction of marked fish in the catch (m/c) in shallow water (Table 4). The marked fraction in BHT fished ≤ 6 m (m/c = 0.150) was significantly lower (P = 0.016, χ^2 = 5.8) than the m/c in BHT ≥ 6 m (m/c = 0.358). Similarly, the marked fraction in shoreline H&L sampling (SH&L, i.e. casting lures ≤ 6 m, m/c = 0.076) was significantly lower (P = 0.007, χ^2 = 7.4) than for DH&L >6 m (m/c = 0.250).

We captured 456 unique cutthroat trout between 180 mm and 317 mm FL during trip 3 (August 5 to August 14), and 119 of these had been previously marked (Table 5). M/C ratios from BHT remained notably dissimilar by depth (≤6 m vs. >6 m, P<0.001, χ^2 = 12.8) despite the greater emphasis placed on nearshore sampling in trip 2**.** Tag loss increased dramatically for VI tags in the 1+ month prior to the third sampling trip (from 3.5% to at least 46%) but remained low for T-bar tags (4% overall, Tables 6 and 7).

Changes in CPUE by gear type and location were often dramatic between sampling trips. For example, CPUE by BHT for fish ≥180 mm FL in trip 2 was only 42% of CPUE during trip 1 (0.059 vs. 0.025), while CPUE for fish <180 mm FL in trip 2 dropped to just 25% of CPUE during trip 1 (0.035 vs. 0.0088, Table 2). These changes in overall CPUE resulted largely from reductions

Table 2.–Sampling effort (hours), catch, and catch per-unit-effort (CPUE, fish per hour) by trip, gear, and species, McKinney Lake, 1996. Tabled values include fish captured more than once in a period, and fish caught with "unusual" gear types not included in sampling for the mark recapture experiment (e.g., PBHT during trip 1 was not used to capture fish for the mark recapture experiment).

			Cutthroat trout $\geq$180 mm		**Cutthroat trout <180 mm**		**Dolly Varden**	
Trip	**Gear** [a]	**Effort**	Catch	CPUE	Catch	CPUE	Catch	CPUE
1	BHT	7,772	459	0.059	275	0.035	1,345	0.17
	PBHT	1,918	9	0.005	0		45	0.02
	Subtotal		468		275		1,390	
2	BHT	5,664	144	0.025	50	0.0088	1,283	0.23
	DH&L	192	44	0.23	0		2	0.01
	SH&L	33.4	196	5.87	45	1.35	0	
	PBHT	3,585	24	0.007	0		204	0.06
	PH&L	15.7	12	0.77	0		0	
	Subtotal		420		95		1,489	
3	BHT	4,971	208	0.042	69	0.014	1,753	0.35
	SBHT	2,071	134	0.06	368	0.18	178	0.09
	SH&L	73.7	114	1.55	16	0.22	0	
	PBHT	2,088	12	0.006	5	0.002	97	0.05
	PH&L	11.5	12	1.04	0		0	
	Subtotal		480		458		2,028	
Total			1,368		828		4,907	

[a] BHT = baited hoop trap distributed uniformly across lake bottom
SBHT = shoreline baited hoop trap—i.e., BHT set along the shoreline
SH&L = shore H&L—i.e., casting near shore
DH&L = downrigger H&L—i.e., trolling with H&L gear using a downrigger
PBHT = pelagic baited hoop trap—i.e., BHT suspended in pelagic (surface) waters
PH&L = pelagic H&L—i.e., trolling with H&L gear in pelagic (surface) waters

Table 3.—Numbers and lengths of cutthroat trout caught and tagged by gear, tag type, and depth, sampling trip 1, McKinney Lake, 1996.

Gear type [a]	**Depth range**	**Catch**	**VI tags**	**T-bar tags**	**Mean depth (m)**	**Mean length (mm)**
BHT	≤6 m	270	140	130	2.8	218
"	>6 m	144	68	76	10.5	231
"	All	414	208	206	5.5	222
PBHT [b]	All	9	5	4	9.1	240
Total	All	423	213	210	5.5	223

[a] BHT = baited hoop trap distributed uniformly across lake bottom
PBHT = pelagic baited hoop trap—i.e., BHT suspended in pelagic (surface) waters

[b] Captures with PBHT not included in the mark-recapture experiment.

Table 4.–Numbers and lengths of cutthroat trout caught, tagged, and recaptured by gear, tag type, and depth, sampling trip 2, McKinney Lake, 1996.

			Newly captured and tagged			Recaptured					
Gear type [a]	Depth range	Total catch [c]	VI tagged	T-bar tagged	Total tagged	VI recaps	T-bar recaps	Total recaps[m]	m/c	Mean depth (m)	Mean length (mm)
BHT	≤6 m	40	17	17	34	4	2	6	0.150	3.8	223
"	>6 m	95	28	33	61	11	23	34	0.358	10.5	239
"	All	135	45	50	95	15	25	40	0.296	8.5	234
SH&L	≤6 m	184	84	86	170	7	7	14	0.076	na[b]	217
DH&L	≤6 m	18	7	7	14	3	1	4	0.222	3.6	245
	>6 m	24	7	11	18	3	3	6	0.250	10.9	238
	All	42	14	18	32	6	4	10	0.238	7.8	241
PBHT	All	22	11	8	19	0	3	3	0.136	4.8	247
PH&L	≤5 m	12	7	4	11	1	0	1	0.083	na	247
Total	All	395	161	166	327	29	39	68	0.172	na	228

[a] BHT = baited hoop trap distributed uniformly across lake bottom

SH&L = shore H&L—i.e., casting near shore

DH&L = downrigger H&L—i.e., trolling with H&L gear using a downrigger

PBHT = pelagic baited hoop trap—i.e., BHT suspended in pelagic (surface) waters

PH&L = pelagic H&L—i.e., trolling with H&L gear in pelagic (surface) waters

[b] na = not applicable

Table 5.—Numbers and lengths of cutthroat trout caught, tagged, and recaptured by gear and depth, sampling trip 3, McKinney Lake, 1996.

Gear type [a]	Depth range	No. catch [c]	No. tagged	No. recaps [m]	m/c	Mean depth (m)	Mean length (mm)
BHT	≤6 m	66	54	12	0.182	3.6	225
"	>6 m	127	71	56	0.441	10.8	237
"	All	193	125	68	0.352	8.4	233
SBHT	≤6 m	129	100	29	0.225	2.6	214
SH&L	≤6 m	111	93	18	0.162	na[b]	222
PBHT	All	12	8	4	0.333	5.2	228
PH&L	≤5 m	11	11	0	0.000	na	229
Total		456	337	119	0.261	na	224

[a] BHT = baited hoop trap distributed uniformly across lake bottom
SBHT = shoreline baited hoop trap—i.e., BHT set along the shoreline
SH&L = shore H&L—i.e., casting near shore
DH&L = downrigger H&L—i.e., trolling with H&L gear using a downrigger
PBHT = pelagic baited hoop trap—i.e., BHT suspended in pelagic (surface) waters
PH&L = pelagic H&L—i.e., trolling with H&L gear in pelagic (surface) waters

[b] na = not applicable

Table 6.—Numbers of cutthroat trout tagged, recaptured, and number of lost tags by gear, tag type, and depth, sampling trip 3, McKinney Lake, 1996.

		Newly tagged		Recaptured fish			
Gear type [a]	Depth range	VI tagged	T-bar tagged	VI recaps [b]	T-bar recaps [b]	VI tags lost	T-bar tags lost
BHT	≤6 m	27	27	8	4	2	0
"	>6 m	32	39	27	29	9	1
"	All	59	66	35	33	11	1
SBHT	≤6 m	47	53	16	13	9	1
SH&L	≤6 m	46	47	7	11	6	0
PBHT	All	4	4	2	2	0	0
PH&L	≤5 m	4	7	0	0	0	0
Total		160	177	60	59	26	2

[a] BHT = baited hoop trap distributed uniformly across lake bottom
SBHT = shoreline baited hoop trap—i.e., BHT set along the shoreline
SH&L = shore H&L—i.e., casting near shore
DH&L = downrigger H&L—i.e., trolling with H&L gear using a downrigger
PBHT = pelagic baited hoop trap—i.e., BHT suspended in pelagic (surface) waters
PH&L = pelagic H&L—i.e., trolling with H&L gear in pelagic (surface) waters

[b] Including the numbers of VI or T-bar tags lost.

Table 7.—Numbers of cutthroat trout recaptured by tag type during sampling trip 3 according to prior capture history, the subset of the recaptures that had lost their primary tag, and calculated rates of tag loss, McKinney Lake, 1996. The 16 fish with lost VI tags in trip 2 had missing adipose fins and lower caudal clips (Table 1), showing they were seen in trip 2 *or* in trips 1 and 2. As some of these 16 fish were likely observed in trips 1&2, related statistics (in bold italics) are biased.

	Previously captured in:			
	Trip 1	Trip 2	Trips 1 & 2	Total
Total	50	***53***	***16***	119
VI recaptured	31	***25***	***4***	60
Lost VI	10	***16***	***0***	26
T-bar recaptured	19	28	12	59
Lost T-bar	1	1	0	2
VI loss rate [a]	***0.32*** [b]	***0.64*** [c]		***0.46*** [d]
T-bar loss rate [a]	0.053	0.036		0.043

[a] Rate for trip 1 = # lost trip 1 / (# seen trip 1 + # seen trips 1 & 2); rate for trip 2 = # lost trip 2 / # seen trip 2; total rate = # lost / (# seen trip 1+# seen trip 2).

[b] Minimum; some of the 16 listed for trip 2 were tagged in trip 1.

[c] Maximum; some of the 16 listed for trip 2 were tagged in trip 1.

[d] Minimum; some of the 25 sampled in trip 2 also sampled in trip 1.

in CPUE at shallow depths (Figure 2). Changes in CPUE were also evident between trips 2 and 3: rates for H&L dropped about 75% while rates with BHT increased (Table 2).

The distribution of fish lengths captured varied substantially by type of gear and where the gear was fished (Figure 3, Tables 3–5). In general, BHT and H&L gear set near shore (≤6 m depths) yielded smaller fish than did gear set offshore or fished in deep water. For example, fish caught in BHT ≤6 m were significantly smaller (KS test, $d_{max} = 0.37$, $P < 0.001$) than fish caught in BHT >6 m during trip 2 (Figure 3, Table 4). The distribution of fish lengths also varied by trip: fish caught in trip 1 were smaller than in trips 2 and 3 (Figure 4).

Water temperatures during trip 1 (early June) declined steadily as depth increased to about 5 m (Table 8). By trip 3 (August) temperatures in the top 3 m of the water column were nearly constant, then they declined rapidly as depth increased to about 6 m.

TRAP AVOIDANCE

Ten (10) of 42 fish (24%) captured by DH&L and 40 of 135 (30%) fish captured by BHT during trip 2 had been captured in traps and marked during the first sampling trip (Table 4). The null hypothesis that recapture rates in BHT would be equal to or higher than recapture rates in DH&L was thus accepted (P = 0.23) since $T = 0.73 > -1.282$. This conclusion was in fact obvious since recapture rates were higher with BHT than with DH&L.

The low sample sizes in trip 1 (68% of planned) and trip 2 (45% and 14% of planned for BHT and DH&L) led to a large reduction (from 80%) in the desired power of the trap avoidance experiment. Assuming the true marked fraction in the population sampled on the lake bottom during trip 2 was as measured ($m/c = 0.282 = [10+40]/[42+135]$), the power of the experiment to detect the alternative hypothesis, if it was true, was reduced to about 32%.

TAG EFFECT

Twenty-nine (29) VI tags and 39 T-bar tags were recaptured during trip 2 (Table 4). The null hypothesis that fish marked with VI tags would be recaptured at equal or lower rates than fish marked with anchor T-bar was accepted since $T = 161 < y_r = 172.6$. The same hypothesis was also accepted when recapture data from Trips 2 & 3 were pooled (Tables 4 and 5, $T = 221$, $y_r = 234.5$).

ABUNDANCE

Because of the high rate of VI tag loss after the second sampling trip (Table 7), only the anchor T-bars were used to estimate abundance. The distribution of lengths of 59 fish recaptured during event 2 (sampling trip 3) was similar to the

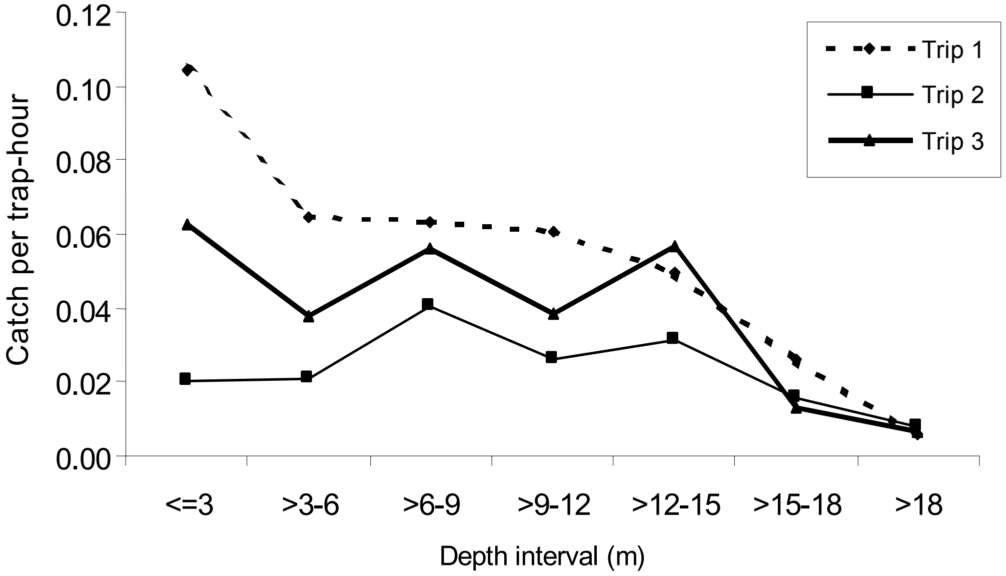

Figure 2.–Catch per trap-hour of cutthroat trout ≥ 180 mm FL in baited hoop traps (BHT) by depth interval and sampling trip, McKinney Lake, 1996.

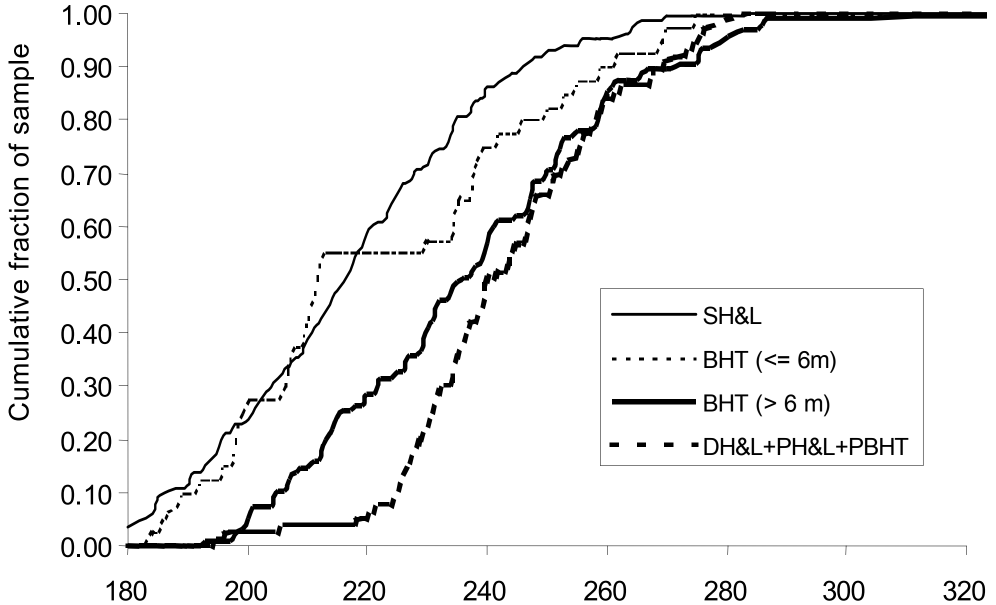

Figure 3.–Cumulative distribution of cutthroat trout lengths sampled by gear, trip 2, McKinney Lake, 1996. Samples were collected by hook and line casting near shore (SH&L), trolling lures in bottom water with downriggers (DH&L) or along the surface of offshore water (PH&L), and baited hoop traps set on the lake bottom (BHT) or near the surface of offshore waters (PBHT). Length distributions by DH&L, PH&L, and PBHT were similar, and thus pooled.

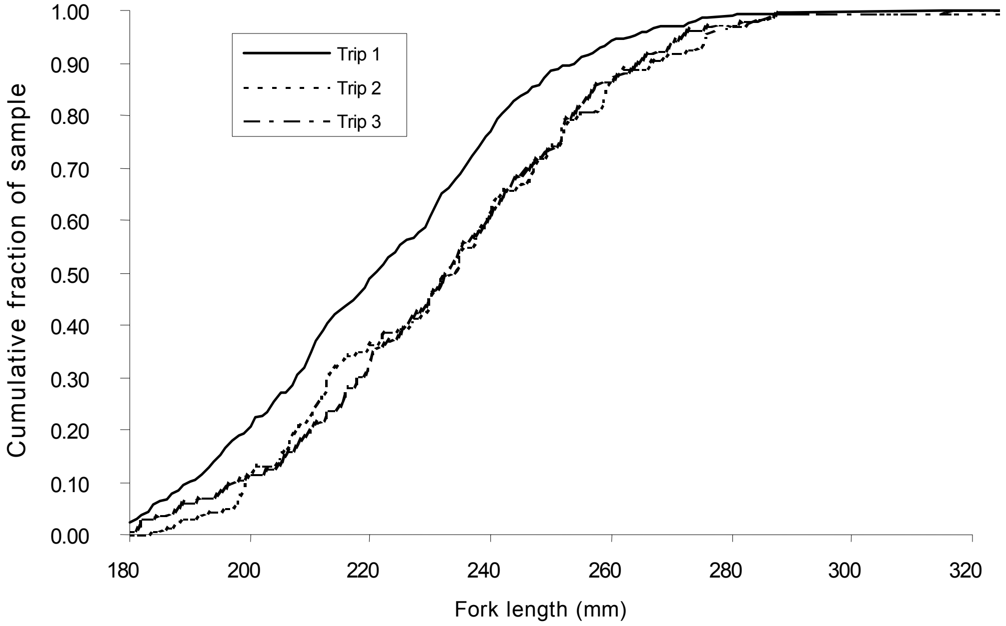

Figure 4.–Cumulative distribution of cutthroat trout lengths sampled with baited hoop traps by trip, McKinney Lake, 1996.

Table 8.–Water temperature, by date and depth, McKinney Lake, 1996.

	Dates							
Depth (m)	3-Jun	5-Jun	8-Jun	28-Jun	1-Jul	6-Aug	8-Aug	12-Aug
Surface	18.6	15.6	13.9	15.9	13.4	16.5	16.0	15.5
0.5	17.4	15.4	13.9	15.9	13.4	16.5	16.0	15.5
1	17.0	14.5	14.0	15.9	13.3	16.5	16.0	15.5
2	13.2	13.3	14.0	15.7	12.7	16.0	16.0	15.0
3	10.6	12.0	10.9	13.3	11.9	16.0	16.0	15.0
4	8.8	8.9	7.4	9.8	11.7	12.5	15.5	14.0
5	7.4	7.0	6.6	7.4	8.8	10.0	10.5	11.5
6	6.5	6.2	6.3	6.7	7.2	7.5	8.0	6.5
7	6.0	5.8	6.0	6.2	6.3	6.5	6.5	6.5
8	5.7	5.5	5.8	5.9	6.0	6.0	6.0	6.0
9	5.4	5.3	5.6	5.8	5.8	5.5	6.0	5.5
10	5.1	5.1	5.4	5.5	5.6	5.5	6.0	5.5
Sample trip	1	1	1	2	2	3	3	3
Weather	clear	clear	rain	rain	showers	showers	rain	rain

distribution of 372 fish marked in event 1 (sampling trips 1 and 2, $d_{max} = 0.14$, $P = 0.29$, Figure 5). Thus, the second sampling event was not size-selective, and stratification based on length was unnecessary (Appendix A). A spatially stratified (6 x 6) summary of the m-r data was then constructed for further analysis (Table 9).

Both consistency tests for use of a pooled Petersen model were rejected ($P<0.01$) using the spatially stratified data (Table 9). Also, a hypothesis of equal marked fractions for fish captured in deep (>6 m) and shallow (≤6 m) areas was rejected ($\chi^2 = 13.4$, $P < 0.001$) and a similar hypothesis of equal marked fractions by lake area (ends and middle of the lake) was rejected ($\chi^2 = 10.4$, $P = 0.005$). Additional contingency table analysis showed these test results were largely caused by heterogeneity in the marked fractions with depth in area C. Thus, a Darroch model for partial mixing (Table 9) was used to estimate abundance. Four fish captured with lost tags (Table 9) were assigned to marking strata based on the relative frequencies of recaptures in the appropriate recovery strata. Similarly, 22 fish captured with H&L (all at depths ≤6 m) did not have their recovery area recorded and they were proportionally allocated to "shallow" strata. Finally, 12 marked fish that did not have their marking area recorded were proportionally allocated to marking strata.

Inadmissible estimates (at least one estimated probability of capture and stratum abundance < 0) were obtained when we applied the Darroch model to the spatial stratified data. Partial pooling of the strata was therefore used to reduce model dimensions. Admissible estimates were obtained only when areas A, B, and C were (individually) pooled over depth (3 strata). Acceptable recovery strata occurred only when area A was pooled over depth. Both consistency tests remained highly significant as the number of strata was reduced through pooling. Thus, the complete elimination of strata and use of the pooled Petersen model was inappropriate. Abundance during early August was estimated as 3,756 (SE = 798) by pooling over depth for area B but not area C.

LENGTH COMPOSITION

Since sampling during the second sampling event was not size selective ($P = 0.29$, see above) and length frequency distributions of cutthroat trout captured during the first and second sampling events were similar ($d_{max} = 0.043$, $P = 0.67$), length composition was estimated using all fish sampled (Table 10, Appendix A). About 45% of the fish were from 180 mm to 220 mm FL and about 98% were ≤280 mm FL. Harvest of cutthroat trout in McKinney Lake is currently limited to fish >287 mm FL (minimum size limit of 12 in TL); less than 1% of the cutthroat trout ≥180 mm FL in McKinney Lake exceed this length.

PELAGIC CATCH RATES

CPUE in the mid-water pelagic traps (PBHT) was stable over time and averaged 12% (weighted average over 3 trips) of the rate for BHT (Table 2). Catch rates for PBHT were highest in the upper 6 m, then declined sharply at greater depths (Figure 6). CPUE with hook and line in offshore surface waters (PH&L) was 13% of the CPUE for casting lures along the shore during trip 2, but increased to 67% of the CPUE for casting lures during trip 3. During trip 2, CPUE for PH&L was 3.3 times the CPUE for trolling lures near the lake bottom (DH&L).

Some mixing of marked fish into the offshore surface waters of the lake occurred during the experiment, but it was obviously not complete. For example, only 2% (1 of 39) of the fish captured in offshore pelagic/surface waters and marked during trips 1 or 2 were ever recaptured during sampling trips 2 or 3 at McKinney Lake. This is much below, for example, the average recapture rates of 17% for trip 2 (Table 4) or 26% for trip 3 (Table 5). In contrast, 12% (4 of 34) of the fish captured with PBHT and PH&L in offshore pelagic/surface waters during trip 2 (Table 4) had been captured with BHT set on the lake bottom during trip 1, and during trip 3 the offshore recapture fraction was 17% (4 of 23 fish; Table 5). The relatively low m/c ratios found in pelagic areas with PBHT and PH&L were similar to those found along the shoreline with BHT and H&L during the same trips.

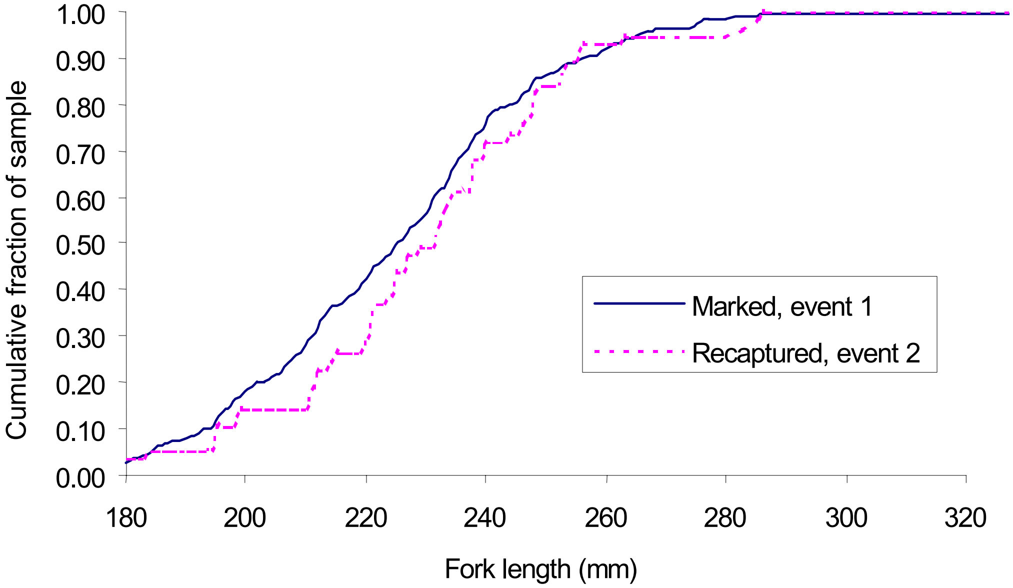

Figure 5.—Cumulative distribution of lengths of cutthroat trout marked during sampling event 1 versus lengths of cutthroat trout recaptured during sampling event 2, McKinney Lake, 1996.

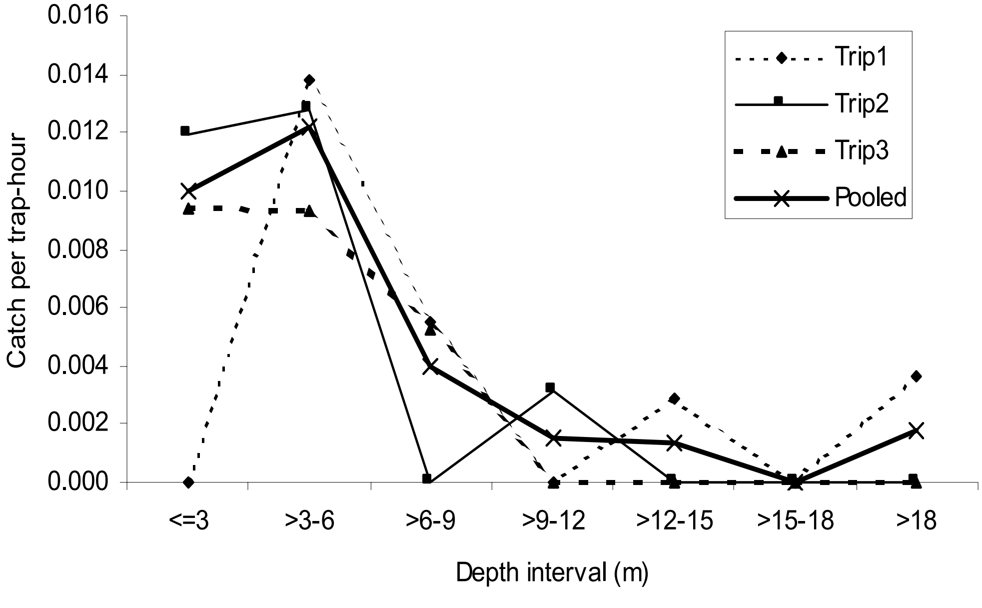

Figure 6.—Catch per unit effort (CPUE) of cutthroat trout versus depth of set for baited hoop trap suspended in offshore surface waters of McKinney Lake, 1996.

Table 9.—Number of anchor T-bar tagged cutthroat trout recovered (m_{ij}) by tagging and recovery strata (areas A, B, C and depths ≤6 m, >6 m), marked by strata (a_i), and unmarked captures by strata (u_j) during the third sampling trip (event 2) at McKinney Lake, 1996. Marking (event 1) occurred during the first and second sampling trips. The marked fractions in each recovery strata ($m_{.j}/(u_j+m_{.j})$) and the fractions recovered from each marking strata ($m_{i.}/a_i$) helped guide decisions about pooling strata.

Marking strata	a_i	Recovery strata							$m_{i.}/a_i$
		Unknown	A		B		C		
		≤6 m	≤6 m	>6 m	≤6 m	>6 m	≤6 m	>6 m	
A ≤6 m	86		7	1	0	0	1	0	0.10
>6 m	41		1	2	0	0	0	0	0.07
B ≤6 m	77		1	0	0	1	1	1	0.05
>6 m	39		1	1	4	2	0	1	0.23
C ≤6 m	73		0	0	3	1	6	4	0.19
>6 m	44		0	1	0	1	3	11	0.36
Unknown	12				1	1	1	1	
	U_j	22	72	20	117	47	83	36	
$m_{.j}/(u_j+m_{.j})$			0.12	0.20	0.06	0.09	0.12	0.31	

Table 10.—Estimated length composition (p_a) and abundance (N_a) for cutthroat trout ≥180 mm FL, McKinney Lake, 1996.

Fork length (mm)	p_a	$SE[p_a]$	N_a	$SE[N_a]$
180 – 200	0.196	0.011	736	162
201 – 220	0.257	0.012	965	210
221 – 240	0.279	0.013	1048	228
241 – 260	0.183	0.011	689	152
261 – 280	0.070	0.007	264	62
281 – 300	0.012	0.003	45	15
301 – 320	0.002	0.001	6	4
>321	0.001	0.001	3	3

FISH MOVEMENT

Changes in depths and locations of capture for all recaptured fish were sorted into three groups based on the length of time between captures: 1) ≤ 30 days, 2) >30-55 days, and 3) >55 days. Histograms of movements (relative frequency of meters traversed or depth changed) were similar by time at large (Figures 7 and 8).

The median changes in depth and distance between all captures were small, at –1.2 m and 265 m, respectively. Changes in depth ranged from –16 m to +15 m, while distances traversed ranged from 0 to 3,085 m. About 50% of all recaptures were within 3 m of the initial depth of capture, and 75% were within 6 m. About 57% of the recaptures were within 300 m of the initial location of capture (i.e., within neighboring grids) and 77% were within 600 m.

DISCUSSION

Our sampling at McKinney Lake was unusually thorough. The sampling design was similar to other studies (e.g., Harding 1995, Der Hovanisian and Marshall 1995, Freeman et al. 1998, Schmidt et al. 1998) in Southeast Alaska where area but not depth were considered when modeling the data. McKinney Lake is similar to other lakes on Admiralty Island in that it contains a rich diversity of high quality shoreline habitat for fish. Perhaps because it is a relatively small lake (about 126 ha), it is also a very productive lake (30 cutthroat trout ≥ 180mm/ha) for Southeast Alaska (Der Hovanisian and Marshall 1995:12).

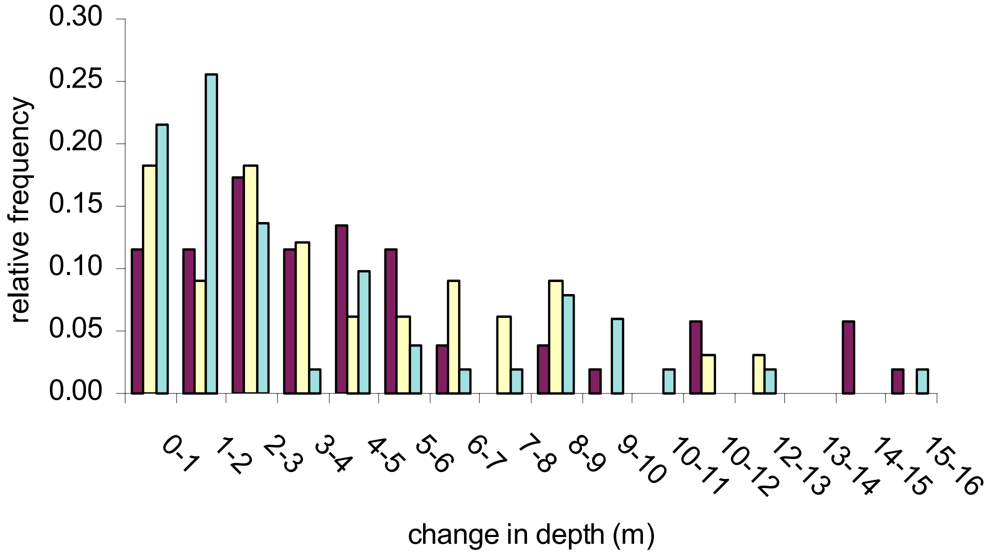

Figure 7.—Change in depth (absolute value) of cutthroat trout recaptured after 3 lengths of time at large, McKinney Lake, summer 1996. Bars on the left, center, and right at each depth represent frequencies after ≤30, >30-55, and >55 days.

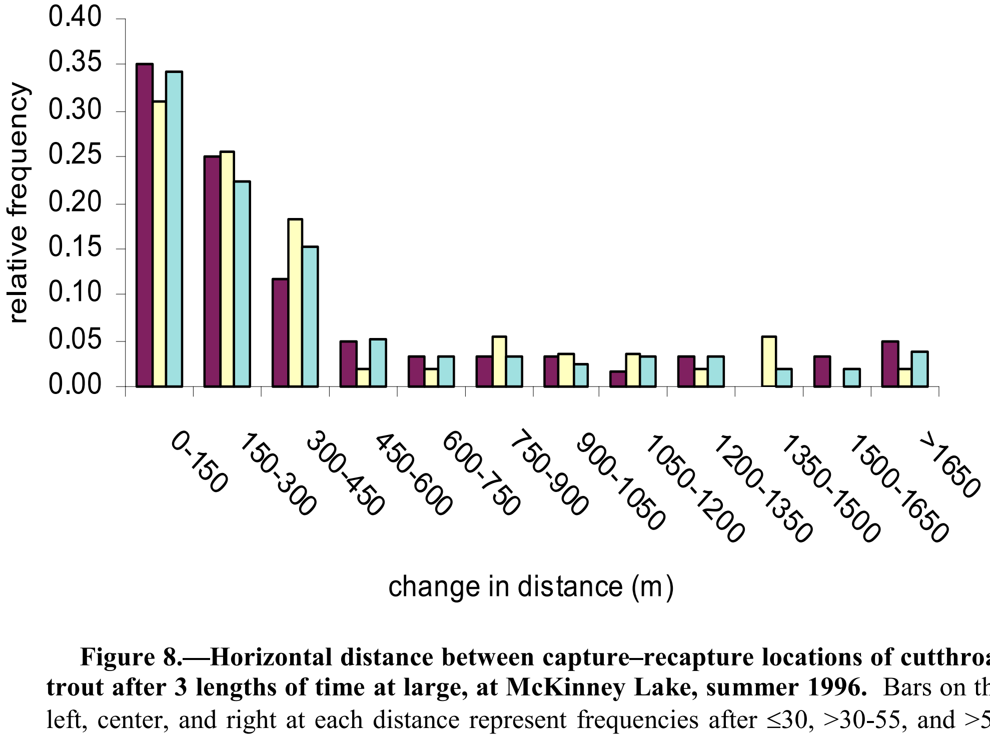

Figure 8.—Horizontal distance between capture–recapture locations of cutthroat trout after 3 lengths of time at large, at McKinney Lake, summer 1996. Bars on the left, center, and right at each distance represent frequencies after ≤30, >30-55, and >55 days.

The relatively smaller sizes of fish caught during trip 1 at McKinney Lake (Figure 4) may reflect that the immigration of larger, spawning fish (from streams) into the lake was not completed on May 31 when sampling began. However, an unbiased abundance estimate for the population was still possible since any immigrant post-spawning fish were most surely residents of the lake during the second sampling event.

Limited movements of marked fish (Figures 7 and 8) and the persistence of dissimilar m/c ratios (Tables 4 and 5) by geographic area and depth during our sampling is noteworthy. If these observations reflect common situations, complete mixing of marked fish may never occur during a typical CP m-r experiment to estimate abundance of cutthroat trout in a similar-sized (126 ha) or larger lake. Thus, the equal probability of capture assumptions may be critically important in these experiments. Models to estimate abundance when mixing is incomplete and probabilities of capture vary by area can in theory greatly reduce bias, but practical limits can reduce or eliminate the use and advantages of these models. For example, in this experiment the two factors (depth and lake area) important for stratification reduced within strata sample sizes to a point where the models were difficult to estimate. Furthermore, if our experiment had consisted of only the first two closely spaced sampling trips (as CP experiments frequently are) stratification based on length would also have been indicated (KS test, P = 0.003), and estimation of the (length, depth and area stratified) model would be more problematic. Also, a significant degree of confounding may exist between factors (e.g., fish size varies by depth and area), as was also noted at Baranof Lake (Der Hovanisian and Marshall 1995). Clearly, sampling designs capable of equalizing probabilities of capture over the important spatial habitats of a lake are highly desirable, but they can be hard to obtain when a single gear type (BHT in our example) is evenly distributed across the lake to be sampled.

In this study, the narrow shoreline habitat of McKinney Lake appeared to be sampled at a relatively low rate when BHT were “uniformly” distributed across the lake during trip 1 (i.e., m/c declines near shore, Tables 4 and 5). Adding another sampling component (also fishing along the shoreline with H&L and BHT) during trip 2 provided for a better distribution of marks. Still, m/c ratios retained the shoreline/depth pattern more than a month later, during the third sampling trip (Table 5). Means to obtain an appropriate balance of sampling effort between gears and habitats may thus require some prior experience, and may vary from lake and one time of year to another.

Potential causes for the low m/c ratios near shore include that gear CPUE declines (becomes depensatory) as population density increases near shore, or that “home ranges” of fish using near shore habitat are smaller than ranges for fish using offshore habitat. Both seem plausible. CPUE data suggest population density is higher near-shore, and fish captured at depth may roam further for food, and thus experience higher trap-encounter rates than fish captured in shallow water. Still another explanation for the relatively low m/c ratios near shore is that young fish recruited to this area, perhaps from streams, during the first and second sampling trips. However, this later explanation seems unlikely because mean lengths of fish captured near shore (in BHT for example) did not change from trip to trip (Tables 3–5).

Detailed knowledge of the seasonal distribution and use of lacustrine habitats by cutthroat trout in Southeast Alaska is limited. The distribution of larger fish in the deeper (>6 m) areas at McKinney Lake in early June is, for example, opposite to the general trend observed at Baranof Lake at a similar time (Der Hovanisian and Marshall 1995:11). We guess that differences in CPUE observed over time (Table 2, Figure 2) are related not only to changes in density, but to changing metabolic needs and food preferences of the fish. The decline in nearshore CPUE from BHT (Figure 2) and SH&L (Table 2) over time, and the subsequent capture of marked fish in offshore surface sampling (PBHT and PH&L), but not the reverse, suggests a net offshore migration of fish during the spring or summer. Limited mixing between deep and shallow lake areas during the summer as suggested by Havens et al. (1992) and Rosenkranz et al. (1999) may also have occurred at McKinney Lake during this experiment. The sharp change in water temperature at depths between 3 and 5 m (Table 8) may have provided a natural boundary (thermocline) that limited the mixing of marked fish between the shallow and deep portions of the lake during this experiment.

The importance of sampling offshore pelagic/ surface waters when estimating abundance merits additional research. Catch rates in these areas in this study were small fractions (e.g., 12% for BHT) of the rates in lake bottom and shoreline areas but we do not dismiss them as insignificant given the very large volume of water present in the offshore surface waters of the lake. Also, fish caught in these areas, and with H&L when trolling along the lake bottom, were larger than fish caught in other areas during the first two sampling trips (Figure 3, Tables 2–5). Pelagic catch rates in McKinney were highest ≤6 m below the lake surface (Figure 6). In contrast, catch rates for cutthroat trout in a much larger lake in Washington State (Lake Washington) were higher offshore than onshore during the spring, summer, and autumn, and catch rates at these times peaked at depths of 10 to 30 m (Beauchamp et al. 1992).

Our study provided no suggestion that cutthroat trout avoided recapture by baited traps after a 2+ week hiatus from sampling. Also, the type of tags implanted (anchor T-bar or VI) appeared not to affect subsequent recapture rates. Unfortunately, our sample sizes were much lower than expected and experimental power to detect significant differences suffered accordingly. Beside the small sample sizes, other caveats are germane to these experiments. First, the form of trap avoidance considered in this study is very different from a lethargic reaction (due to the handling and tagging process) that would lower catchability by *any* gear type requiring an active response of the fish. Second, the VI tagging procedure used in this study is assumed to be less invasive than inserting anchor T-bar tags. However, due to our relative inexperience with this method, the VI tagging procedure required a substantial amount of handling, and could thus have been equally or more stressful than the handling required to implant anchor tags. Recent experiments at Florence Lake (Harding 1999) suggest the amount of handling (e.g., as might result from a lack of experience or taking additional measurements like length) and tagging (e.g., use of multiple marks and clips) can have profound negative effects on subsequent survival and recapture rates.

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APPENDIX A

Appendix A1.–Detection of size-selective sampling (from Bernard and Hansen 1992).

	Result of Hypothesis Test on Lengths of fish CAPTURED during the First Event and RECAPTURED during the Second Event	**Result** of Hypothesis Test on Lengths of fish CAPTURED during the First Event and CAPTURED during the Second Event	
Case I:	**Accept H_o**	**Accept H_o**	There is no size-selectivity during either sampling event.
Case II:	**Accept H_o**	**Reject H_o**	There is no size-selectivity during the second sampling event but there is during the first.
Case III:	**Reject H_o**	**Accept H_o**	There is size-selectivity during both sampling events.
Case IV:	**Reject H_o**	**Reject H_o**	There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.

Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Use lengths, ages, and sexes from only the second sampling event to estimate proportions in compositions, and apply formulae to correct for size bias to the data from the second event.

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the two estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for Cases III or IV. However, if the two estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during the second event (Cases I or II).

Appendix A2.–Data files used in preparation of this report.

File name	Description
McKn_96_FDS.xls	Sampling data and summaries used to produce estimates. MS Excel file.
Mc_move.xls	Summaries of fish movements (distance, depth) over time. MS Excel file.
99mckinney_v97.doc	This report. MS Word 97 file.